09/305780

TELECENTRIC LENS SYSTEMS FOR FORMING AN IMAGE OF AN OBJECT COMPOSED OF PIXELS

FIELD OF THE INVENTION

This invention relates to telecentric lens systems and. in particular. to systems of this type which can be used. inter alia. to form an image of an object composed of pixels. such as. a liquid crystal display (LCD) or a discrete mirror device (DMD). In certain embodiments. the lens systems have a long aperture stop to object distance (ASOD). a high level of aberration correction. a large aperture. and a wide field of view. The invention further relates to the use of such lens systems in projection televisions. e.g.. rear projection televisions. in which an image of an LCD. DMD. or other pixelized panel is projected onto a viewing screen.

BACKGROUND OF THE INVENTION

Projection television systems employing LCDs or DMDs are currently under development for use as. among other things. computer monitors. Such projection televisions preferably employ a single lens system which forms an image of either a single panel having. for example. red. green. and blue pixels. or three individual panels. one for each color.

In either case. and. in particular. in the three panel case. the lens system normally needs to have a long aperture stop to object distance (ASOD) to accommodate the optical elements. e.g.. filters. beam splitters. prisms. and the like. used in combining the light from the different color optical paths which the lens system projects towards the viewing screen.

The illumination of a pixelized panel plays an important role in the performance of projection TVs employing such panels. In particular. it is important to match the location and size of the exit pupil of the illumination system with the entrance pupil of the lens system to obtain a bright. uniformly-illuminated image on the TV screen. Since illumination optics generally work best when the exit pupil is located a long distance from the light source. it is desirable to use a projection lens system with a long entrance pupil distance. Also. LCD panels work best when light passes through them at small angles.

Telecentric lens systems are systems which have at least one pupil at infinity. In terms of principal rays. having a pupil at infinity means that the principal rays are parallel to the optical axis (a) in object space. if the entrance pupil is at infinity. or (b) in image space. if the exit pupil is at infinitum. Since light can propagate through a lens system in either direction. the pupil at infinity can serve as either an entrance or an exit pupil depending upon the system's orientation with respect to the object and the image. Accordingly. the term "telecentric pupil" will be used herein to describe the system's pupil at infinity. whether that pupil is functioning as an entrance or an exit pupil.

In practical applications. the telecentric pupil need not actually be at infinity since a lens system having an entrance or exit pupil at a sufficiently large distance from the system's optical surfaces will in essence operate as a telecentric system. The principal rays for such a system will be substantially parallel to the optical axis and thus the system will in general be functionally equivalent to a system for which the theoretical (Gaussian) location of the pupil is at infinity.

Accordingly. as used herein. the term "telecentric lens system" is intended to include lens systems which have at least one pupil at a long distance from the lens elements. and

the term "telecentric pupil" is used to describe such a pupil at a long distance from the lens elements. For the lens systems of the invention, the telecentric pupil distance will in general be at least about 10 times the system's focal length.

In addition to having a long ASOD and a telecentric pupil, lens systems for use with pixelized panels generally need to have a high level of aberration correction, including lateral color correction. Lateral color, i.e., the variation of magnification with color, manifests itself as a decrease in contrast, especially at the edges of the field. In extreme cases, a rainbow effect in the region of the full field can be seen.

In projection televisions employing cathode ray tubes (CRTs) a small amount of (residual) lateral color can be compensated for electronically by, for example, reducing the size of the image produced on the face of the red CRT relative to that produced on the blue CRT. With pixelized panels, however, such an accommodation cannot be performed because the image is digitized and thus a smooth adjustment in size across the full field of view is not possible.

Accordingly, a higher level of lateral color correction is needed from the lens system. In particular, for a VGA computer monitor, the lateral color evaluated across the entire active surface of the pixelized panel(s) over the visual light spectrum should be less than about the diagonal of a pixel and preferably less than about ½ the diagonal of a pixel.

Pixelized panels and their use in computer monitor applications also lead to stringent requirements regarding the correction of distortion and the attainment of flat field imagery, i.e., the achieving of a high level of correction of the field curvature of the lens system. This is so because when viewing data displays, good image quality is required even at the extreme points of the field of view of the lens system. Similarly, it is also important to keep an even illumination level across the image of the pixelized panel, i.e., to maintain the smallest relative illumination fall-off possible due to vignetting in the lens system. Further, various illumination schemes may require lens systems having large numerical apertures, e.g., apertures corresponding to a f-number of 2 or faster.

For rear projection applications, it is desirable to have as small an overall package size (monitor size) as possible. In terms of the optics, this means that the imaging conjugates should be made as small as possible while still maintaining a large image size. This, in turn, means that the projection lens system should have a wide field of view, e.g., preferably a field of view whose half angle is at least about 25° or higher. A lens system having such a field of view is referred to herein as a "wide angle" system.

The lens systems described below address all the above requirements and can be successfully used in producing projection televisions and, in particular, computer monitors, where a high quality color image is required.

DESCRIPTION OF THE PRIOR ART

Lens systems for use -with projection television systems and, in particular, projection televisions using pixelized panels are describe in various patents and patent publications, including Moskovich, U.S. Pat. No. 5,200,861, and Moskovich, U.S. Pat. No. 5,218,480.

Discussions of LCD systems can be found in Taylor, U.S. Pat. No. 4,189,211, Gagnon et al., U.S. Pat. No. 4,425,028, Gagnon, U.S. Pat. No. 4,461,542, Ledebuhr, U.S. Pat. No. 4,826,311, Minefuji, U.S. Pat. No. 4,913,540, EPO Patent Publication No. 311,116, and Russian Patent Publication No. 1,007,068.

Discussions of telecentric lens systems can be found in Hirose, U.S. Pat. No. 4,511,223., Miyamae et al., U.S. Pat. No. 4,637,690, Shirota, U.S. Pat. No. 4,925,279, Ikemori, U.S. Pat. No. 3,947,094, Tateoka, U.S. Pat. No. 4,441,792, EPO Patent Publication No. 373,677, and Russian Patent Publications Nos. 603,938, 1,048,444, and 1,089,535.

An objective lens-for a reflex camera employing two facing meniscus elements is disclosed in Fischer et al., U.S. Pat. No. 4,025,169. The lens of this patent is not suitable for use in producing color images from one or more pixelized panels because, :inter alia, the lens is not telecentric. Also, Fischer et al.'s aperture stop is not located between their facing meniscus elements as is the case in all of the lens systems of the present system.

SUMMARY OF THE INVENTION

In view of the foregoing, it is an object of the present invention to provide proved lens systems for use in projection televisions and, in particular, in computer monitors in which one or more pixeled panels are projected onto a viewing screen.

More particularly, it is an object of the invention to provide lens systems which have at least some, and preferably all, of the following properties: 1) a long ASOD for light traveling from right to left in the figures, i.e., an ASOD which is at least about 2.5 times the focal length (f) of the system, and preferably at least about 3.0 times f (note that as the ASOD/f ratio increases, it becomes more difficult to correct the aberrations of the lens system so as to produce an image suitable for use in displaying data on a computer monitor); 2) a telecentric pupil, i.e., an entrance pupil a long distance from the lens system for light traveling from right to left in the figures; 3) a high level of aberration correction, including correction of distortion, field curvature, and lateral color (note that with a pixelized panel, pincushion and barrel distortion cannot be corrected electronically as can be done to at least some extent in projection televisions that employ cathode ray tubes); 4) a large aperture, e.g., a f-number of about 2; and 5) a wide field of view, i.e., a field of view greater than about 25 degrees half or semi-field for light traveling from left to right in the figures.

To achieve the foregoing and other objects, the invention provides a telecentric lens system which includes the following three lens units in order from the long conjugate side to the short conjugate side of the system:

(1) a first lens unit which:
  (a) has a negative power; and
  (b) includes at least one negative lens element whose strongest surface is convex to the long conjugate side of the system;

(2) a second lens unit which:
  (a) is of weak optical power, i.e., the ratio of the absolute value of the focal length of the second lens unit to the focal length of the lens system is greater than about 1.5;
  (b) comprises two meniscus elements whose concave surfaces face each other; and
  (c) includes the lens system's aperture stop with the aperture stop being located between the meniscus elements; and

(3) a third lens unit which:
  (a) has a positive power;
  (b) forms the system's telecentric pupil by imaging the aperture stop; and
  (c) includes means for correcting the chromatic aberrations of the lens system, including the lateral color of the system.

Preferred constructions for the three lens units are discussed below in connection with the Description of the Preferred Embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1 through 15 are schematic side views of lens systems constructed in accordance with the invention.

FIG. 16 is a schematic diagram of a projection TV/computer monitor employing a lens system constructed in accordance with the invention.

These drawings, which are incorporated in and constitute part of the specification, illustrate the preferred embodiments of the invention, and together with the description, serve to explain the principles of the invention. It is to be understood, of course, that both the drawings and the description are explanatory only and are not restrictive of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

As discussed above, the lens systems of the present invention include three lens units, each of which includes at least one lens element.

I. The First Lens Unit

The first lens unit has a negative power and serves to provide the large ASOD needed to accommodate the optical path folding and/or combining means employed with pixelized panels. As illustrated in the figures, the lens systems of the invention have a large space on the short conjugate side of the system either between the elements of the system (FIGS. 1–8) or after those elements (FIGS. 9–15).

To minimize aberration contributions, the first lens unit includes at least one negative element, preferably the leading element of the unit, which has a strong surface facing away from (convex to) the system's long conjugate. The strong convex surface minimizes the angles of incidence and thus the contribution of the surface to the aberrations of the system. The negative element with the strong surface is preferably meniscus shaped.

The first unit can contain a single negative element (FIGS. 2–3 and 5–15) or multiple negative elements (FIGS. 1 and 4). Where multiple negative elements are used, the elements can all be meniscus shaped (FIG. 1) or can be a combination of meniscus and biconcave elements (FIG. 4).

To minimize lateral color contributions, all the negative elements in the first unit are preferably made of a low dispersion material, i.e., a material having a dispersion like crown glass, such as acrylic in the case of a plastic lens element. As used herein, a low dispersion material is one having a V-value in the range from 35 to 75 for an index of refraction in the range from 1.85 to 1.5, while a high dispersion material is one having a V-value in the range from 20 to 50 for the same range of indices of refraction.

The first lens unit preferably includes one or more aspheric surfaces which provide a major contribution to the correction of the distortion of the system.

II. The Second Lens Unit

The second lens unit contains the system's aperture stop which is located between the two menisci of that unit. The stop can be a lens mount, a separate aperture, or a variable diaphragm depending upon the particular application.

The menisci elements of this unit make a significant contribution to the correction of the field curvature of the lens system. These elements preferably have aspheric surfaces in order to correct other aberrations in the system. Specifically, the aspheric surfaces serve to correct aperture

dependent aberrations, e.g., spherical aberration, as well as coma and other residual aberrations. The correction of spherical aberration by these aspheric surfaces allows fore the achievement of smaller f-numbers for the lens system. By locating the stop between the facing menisci, the odd powered aberrations of these elements, i.e., coma, distortion, and lateral color, are automatically, minimized by the structure of the lens. See, for comparison, the Hypergon lens (U.S. Pat. No. 706,650) and the Topogon lens (U.S. Pat. No. 2,031,792). In this way, the aspheric surfaces of these elements can be used primarily to correct aberrations arising elsewhere in the system.

The second lens unit can include an additional lens element located on the long conjugate side of and directly associated with the first meniscus element, i.e., in contact with or essentially in contact with the first meniscus element (FIGS. 2, 5–7, and 9–15).

This additional element usually has a positive power to enhance the correction of distortion and astigmatism and is made of a high dispersion material (e.g., a flint glass or styrene) to achieve a better correction of lateral color. To improve this correction even further, the element may be made as a cemented doublet as shown in FIG. 11. The lateral color improvement achieved by this additional element occurs through, inter alia, its interaction with the low dispersion negative element(s) of the first lens unit. This combination of a low dispersion negative element and a high dispersion positive element functions in a manner similar to that of an afocal attachment of the type previously used with double Gauss and retrofocus lens systems. See, for example, Kawamura, U.S. Pat. No. 4,046,459, in which two low dispersion negative meniscus elements (elements 1 and 2) and a high dispersion positive element (element 3) are used to correct lateral color.

The additional lens element may also include an aspherical surface(s) to enhance the correction of monochromatic aberrations including distortion, especially, if no aspherical surfaces are used in the first lens unit.

The second lens unit may have a color correcting doublet near the aperture stop of the lens to provide an enhanced correction of the axial color of the lens system (FIGS. 12 and 14). This additional correction may be required when the color correcting doublet in the third lens unit (see below) is designed to provide a particularly fine correction of the system's secondary lateral color and thus is not able to provide a sufficient correction of axial color. By placing the color correcting doublet of the second lens unit near the aperture stop, this doublet can correct axial color without significantly affecting the lateral color correction provided by the color correcting doublet of the third lens unit and the combination of the negative low dispersion lens element or elements of the first lens unit and the positive high dispersion additional lens element of the second lens unit. In certain embodiments, the color correcting doublet of the second lens unit can be composed of materials having abnormal partial dispersions (see Table 14).

III. The Third Lens Unit

The third lens unit has a positive optical power and preferably provides the majority of the positive power of the lens system. The aperture stop of the lens system is located at or near the front focal point of the third lens unit so that the entrance pupil of the lens system for light traveling from right to left in the figures is at a long distance from the lens system, i.e., so that the lens system is telecentric. As can be seen in the figures, a large space characterized by the system's ASOD is provided either within or just behind the third lens unit.

The third lens unit includes a color correcting means. The color correcting means can be a classical color correcting doublet employing a positive low dispersion (crown) element and a negative high dispersion (flint) element. However, as illustrated in Table 12, the color correcting means of the third lens unit can also include a positive and a negative element, each composed of a low dispersion (crown) material, with the material being different for the two elements and with at least one of the materials having an abnormal partial dispersion. The use of such a configuration arises as follows.

Primary lateral color describes the difference in size of the red and blue images formed by a given lens system. In some embodiments of the invention, see, for example FIGS. 11–13, where the lens has a long back focal distance, the off-axis bundles go through the third lens unit at significant heights, larger than the axial beam height. In this situation., secondary lateral color, i.e., the difference in magnification of the red-blue image versus the green image, may become a problem of concern. When this is the case, secondary color can be corrected by the use of materials with abnormal partial dispersions in the color correcting means of the third lens unit (see Table 12). In the process of achieving correction of secondary lateral color, the correction of axial color may be compromised. In this case, an additional doublet in the second lens unit can be used (again see Table 12).

The lens elements of third lens unit will normally include one or more aspherical surfaces which provide correction of pupil spherical aberration as well as contribute to the correction of residuals of spherical aberration, distortion, astigmatism, and coma.

FIGS. 1 to 15 illustrate various lens systems constructed in accordance with the invention. Corresponding lens prescriptions appear in Tables 1 to 15, respectively. Lens units, lens elements, and lens surfaces are identified by "U", "L", and "S" numbers, respectively, in the figures.

As is conventional, the figures are drawn with the long conjugate on the left and the short conjugate on the right. Accordingly, in the typical application of the invention, e.g., in a computer monitor, the viewing screen will be on the left and the pixeled panel or panels will be on the right.

In FIGS. 10–15, the various surfaces appearing after the third lens unit correspond to optical elements, such as mirrors, prisms, and the like, used in forming a color image from pixeled panels. Although not shown in FIGS. 1–9, similar optical elements can be used with the lens systems of these figures. In FIGS. 1–8, a folding mirror (not shown) can be included between the two rear elements of the lens system to reduce the overall size of a projection TV/computer monitor employing the lens system.

The glasses and plastics referred to in Tables 1–15 are set forth in Table 16, where the glass names are the SCHOTT designations. Equivalent materials made by other manufacturers can be used in the practice of the invention.

The aspheric coefficients set forth in the tables are for use in the following equation:

$$z = \frac{cy^2}{1 + [1 - (1+k)c^2y^2]^{1/2}} + ADy^4 + AEy^6 + AFy^8 + AGy^{10} + AHy^{12} + AIy^{14}$$

where z is the surface sag at a distance y from the optical axis of the system, c is the curvature of the lens at the optical axis, and k is a conic constant, which is zero for all of the examples.

The abbreviations used in the Tables 1–15 are as follows: SN—surface number; CLR. AP.—clear aperture; EFL—effective focal length of the system; FVD—front vertex

distance; f/—f-number; IMD—image distance; OBD—object distance; OVL—overall length; OBJ. HT—object height; MAG—magnification; ENP—entrance pupil; EXP—exit pupil; and BRL—barrel length, where the values given are for light traveling from left to right in the figures. The designation "a" associated with various surfaces represents "aspheric". All dimensions given in the Tables 1–15 and 17 are in millimeters.

Table 17 summarizes various of the properties and advantages of the present lens system. The abbreviations used in this table are as follows: Field—half field of view for light traveling from left to right; F/No—f-number; f—effective focal length of the system; f_1, f_2, and f_3—focal lengths of units 1, 2, and 3, respectively; ASOD—aperture stop to object distance for light traveling from right to left; and ENPD—entrance pupil distance for light traveling from right to left.

As shown in Table 17, for all of the examples, the first lens unit has a negative power, the second lens unit is of weak optical power, and the third lens unit is the strongest contributor to the lens system's overall positive power. The table further shows that except for Examples 5, 12, and 14–15, the third lens unit provides the majority of the positive power of the system, where "majority" means that the positive power of the third lens unit is more than twice the positive power of the second lens unit for those second lens units that have a positive power.

As also shown in Table 17, all of the lens systems have a large ASOD, a telecentric entrance pupil, and, except for Example 14 and 15, a wide field of view, i.e., a field of view of 25° or higher. Examples 14 and 15 are designed for use with multiple folding mirrors between the lens system and the viewing screen which allows for a somewhat smaller field of view. Because the field of view is smaller, the viewing screen need not have as large a numerical aperture, which allows for a simpler screen construction. Also, the

smaller field of view means that the illumination at the corners of the screen is higher since the $\cos^4$ dropoff is less.

Table 17 further shows that all of the lens systems of the invention have ASOD/f values that are greater than 2.5 and all but Example 2 have values greater than the preferred value of 3.0, with the value for Example 2 being about 3.0.

FIG. 16 is a schematic diagram of a projection television/computer monitor **10** constructed in accordance with the invention. As shown in this figure, projection television/computer monitor **10** includes cabinet **12** having projection screen **14** along its front face. The image to be projected is formed by module **16** which includes, inter alia, a light source, three pixelized panels, and a set of dichroic beam-splitters for combining the light from the three panels into a single beam. Alternatively, module **16** can include a single, three color, pixelized panel and its associated optical components. Various commercially available components known in the art can be used to construct module **16**.

The single, three-color beam produced by module **16** is projected by lens system **13** onto mirror **18** and ultimately to screen **14**. Lens system **13** is constructed in accordance with the present invention and thus forms a high quality image on the screen. In particular, the distortion is fully corrected, the monochromatic imagery is flat and uniformly bright across the format, and the lateral color across the entire active surface of the pixelized panel or panels over the visual light spectrum is less than about the diagonal of a pixel and preferably less than about ½ the diagonal of a pixel.

Although specific embodiments of the invention have been described and illustrated, it is to be understood that a variety of modifications which do not depart from the scope and spirit of the invention will be evident to persons of ordinary skill in the art from the foregoing disclosure. The following claims are intended to cover the specific embodiments set forth herein as well as such modifications, variations, and equivalents.

TABLE 1

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	100.8190	6.00000	ACRYLIC	107.63
2	48.9744	15.25518		84.97
3a	143.9044	6.00000	ACRYLIC	81.86
4a	43.3618	37.93520		68.93
5a	35.6345	15.00000	STYRENE	54.27
6a	81.6110	17.36272		47.86
7	Aperture stop	7.77990		37.45
8a	−27.2425	6.00000	STYRENE	37.38
9a	−423.3710	0.50000		45.18
10	107.7346	15.00000	SK5	52.75
11	−73.4827	4.00000	SF6	57.31
12	−1002.5660	1.50000		64.58
13	108.4138	23.00000	SK5	80.44
14	−95.4279	0.50000		82.81
15a	133.2972	12.00000	ACRYLIC	84.41
16a	−132.2276	114.48260		83.83
17a	139.3172	15.00000	ACRYLIC	108.80
18	−700.0000	10.00020		108.50

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
1	−1.5934E-07	−3.2301E-11	−8.4041E-15	−1.4417E-18	1.0816E-22	2.0851E-25
3	2.0545E-06	−1.5307E-10	1.8192E-13	7.9530E-17	2.8673E-20	1.1986E-23
4	−9.7451E-08	4.9263E-10	−4.9311E-13	2.6150E-16	3.9054E-19	1.2880E-22
5	−2.3574E-07	−1.3342E-09	5.3174E-12	−7.7048E-17	−1.1073E-17	1.2716E-20
6	−8.2802E-07	1.6251E-09	1.1806E-12	−2.0627E-14	5.0501E-17	−3.3873E-20
8	4.4580E-07	−4.4341E-09	1.5629E-11	9.3004E-15	−1.6550E-16	2.5239E-19
9	8.5180E-07	−1.8891E-10	1.2699E-12	5.1184E-16	−2.8733E-18	3.3000E-21
15	−1.6675E-07	8.4927E-11	3.6771E-14	2.5463E-17	−5.0093E-21	−1.1761E-23

TABLE 1-continued

16	1.7020E-06	2.7211E-10	3.2080E-14	3.7396E-17	−1.0735E-20	−7.5127E-24
17	−1.8602E-07	5.2861E-11	−2.2361E-14	5.1543E-18	−1.9417E-21	4.2479E-25

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −660.40	f/: 2.40	MAG: −0.0800
EFL: 65.6056	FVD: 307.316	ENP: 57.7119
IMD: 10.0002	BRL: 297.316	EXP: −13189.8
OBD: −762.684	OVL: 1070.00	
STOP: 0.00 after surface 7. DIA: 37.446		

TABLE 2

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1	158.7994	8.37562	BK7	95.61
2	38.8752	32.61261		69.13
3a	94.7110	12.00000	STYRENE	63.03
4	−203.5070	0.27919		61.22
5a	42.9601	7.44470	ACRYLIC	46.52
6a	29.5212	27.52002		36.41
7a	−29.5212	7.44470	ACRYLIC	38.06
8a	−42.9601	0.27919		47.24
9	−95.0201	4.18781	SF14	52.65
10	153.0600	18.61174	SK5	63.41
11	−40.9609	0.27919		63.59
12a	−1496.9570	15.00000	ACRYLIC	73.63
13	−76.4720	105.36350		76.70
14a	104.2866	18.00000	ACRYLIC	107.94
15	−535.3889	9.99825		107.71

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
3	1.2971E-06	−1.9595E-10	9.6038E-14	5.3556E-17	−9.0228E-20	1.3068E-22
5	1.8328E-06	−4.7943E-10	1.1410E-11	−1.3831E-14	2.0351E-17	−1.7888E-21
6	2.7335E-06	1.3736E-08	−3.3516E-11	1.0660E-13	−8.6134E-17	2.6188E-19
7	−2.7335E-06	−1.3736E-08	3.3516E-11	−1.0660E-13	8.6134E-17	−2.6188E-19
8	−1.8328E-06	4.7943E-10	−1.1410E-11	1.3831E-14	−2.0351E-17	1.7888E-21
12	−1.7503E-08	−5.9870E-10	5.5361E-13	−1.0991E-16	−2.0521E-19	9.6568E-23
14	−6.5592E-07	−3.0849E-10	3.2824E-13	−1.1758E-16	1.9238E-20	−1.1976E-24

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −660.40	f/: 2.40	MAG: −0.0800
EFL: 65.9995	FVD: 267.397	ENP: 47.5474
IMD: 9.99825	BRL: 257.398	EXP: 933.924
OBD: −772.750	OVL: 1040.15	
STOP: 13.76 after surface 6. DIA: 34.222		

TABLE 3

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	−569.1859	6.00000	ACRYLIC	103.24
2a	43.4332	49.25188		75.58
3a	35.5386	15.00000	STYRENE	54.67
4a	76.6546	17.03723		47.98
5	Aperture stop	8.21508		37.52
6a	−26.8487	6.00000	STYRENE	37.44
7a	−416.2517	0.50000		45.39
8	109.7018	15.00000	SK5	52.67
9	−72.4406	4.00000	SF6	57.25
10	−797.2393	1.50000		64.51
11	109.2625	23.00000	SK5.	80.23
12	−91.7278	0.50000		82.51
13a	161.3874	12.00000	ACRYLIC	83.64
14a	−124.5568	112.67720		83.29
15a	139.8700	15.00000	ACRYLIC	108.82

TABLE 3-continued

16	−700.0000	9.99310		108.53

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
1	1.5269E-06	−4.7793E-10	8.6329E-14	1.7534E-17	−1.0696E-20	1.3478E-24
2	−5.8872E-07	6.2672E-10	−7.1632E-13	8.0158E-17	2.6776E-19	−1.1388E-22
3	−3.5984E-07	−1.2303E-09	5.4687E-12	−1.4090E-16	−1.1096E-17	1.2514E-20
4	−9.0496E-07	2.1367E-09	1.1451E-12	−2.0602E-14	5.0957E-17	−3.5173E-20
6	5.7611E-07	−3.9036E-09	1.9304E-11	8.2042E-15	−1.7730E-16	2.7062E-19
7	9.8174E-07	1.2856E-10	1.0683E-12	9.5925E-17	−2.9673E-18	3.7727E-21
13	−1.6458E-07	4.8211E-11	2.4178E-14	2.1575E-17	−5.9263E-21	−1.0409E-23
14	1.6358E-06	2.6911E-10	1.6924E-14	3.2156E-17	−9.6676E-21	−6.4011E-24
15	−1.4088E-07	5.6379E-11	−3.6038E-14	6.7003E-18	−3.6489E-22	7.2340E-26

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −660.40 f/: 2.40 MAG: −0.0800
EFL: 65.6496 FVD: 295.674 ENP: 46.6887
IMD: 9.99310 BRL: 285.681 EXP: −11068.7
OBD: −774.320 OVL: 1069.99
STOP: 0.00 after surface 5. DIA: 37.505

TABLE 4

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	121.6711	6.00000	ACRYLIC	93.20
2a	41.1280	25.00000		71.09
3a	−107.0244	6.00000	ACRYLIC	75.16
4a	175.4115	20.79812		69.61
5a	37.5326	13.00000	STYRENE	55.66
6a	161.2136	21.18080		52.12
7	Aperture stop	7.23365		36.91
8a	−26.6420	6.00000	STYRENE	36.71
9a	−445.8134	0.50000		43.12
10	104.5622	18.00000	SK5	48.92
11	−39.4092	4.00000	F2	52.24
12	−281.2199	0.50000		60.79
13	200.0000	12.00000	SK5	66.16
14	−200.0000	0.50000		69.13
15a	97.9319	14.00000	ACRYLIC	72.62
16a	−98.6747	114.44620		74.52
17a	122.0959	15.00000	ACRYLIC	108.21
18	−700.0000	9.99830		108.04

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
1	1.5671E-06	−2.9628E-10	6.2129E-14	4.5410E-18	−2.5318E-21	3.2733E-24
2	4.4999E-07	1.2576E-09	−9.5383E-13	6.7316E-17	2.6653E-19	−3.2088E-23
3	2.0585E-07	−5.1256E-12	3.8085E-14	1.4747E-17	−6.1487E-21	−1.0810E-23
4	−1.1286E-06	−8.3704E-11	1.5965E-13	1.2992E-16	1.7118E-19	−1.4586E-22
5	1.9928E-07	−1.0572E-09	2.5608E-12	4.2407E-15	−1.1849E-17	9.8733E-21
6	1.9348E-06	−4.9766E-11	6.1775E-12	−2.3604E-14	3.7314E-17	−1.9697E-20
8	4.2889E-06	−2.9900E-09	1.7108E-11	3.0536E-14	−2.1140E-16	2.7849E-19
9	−3.6942E-07	−9.6501E-10	2.5605E-12	4.5202E-16	−3.0357E-18	8.6693E-22
15	−1.9405E-06	−1.6176E-10	−2.2276E-13	−1.5551E-17	6.7875E-20	−1.7330E-24
16	1.2198E-06	−6.4493E-10	−8.4860E-14	1.4249E-17	9.7658E-21	1.9331E-23
17	−9.2257E-08	−2.8442E-11	−8.2153E-15	6.3747E-18	−3.6829E-21	8.0873E-25

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −660.40 f/: 2.60 MAG: −0.0800
EFL: 66.1922 FVD: 294.157 ENP: 52.2689
IMD: 9.99830 BRL: 284.159 EXP: −6205.57
OBD: −775.838 OVL: 1070.00
STOP: 0.00 after surface 7. DIA: 36.239

TABLE 5

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	-947.4765	8.37562	ACRYLIC	98.83
2	38.9498	50.59302		68.59
3	76.9362	7.44470	SF11	55.16
4	457.8991	0.27919		53.94
5a	78.8922	7.44470	ACRYLIC	51.42
6a	57.2344	33.15717		46.21
7a	-57.2344	7.44470	ACRYLIC	47.74
8a	-78.8922	0.27919		53.35
9	-143.5735	4.18781	SF14	54.86
10	94.6729	18.61174	SK5	60.30
11	-47.1576	0.27919		61.67
12a	127.8837	11.16705	ACRYLIC	64.71
13	1321.2629	120.66400		66.02
14a	91.6236	15.00000	ACRYLIC	108.26
15	-535.3889	9.97716		108.26

EVEN POLYNOMIAL ASPHERES

SN	AD	AE	AF	AG	AH	AI
1	1.0719E-06	-5.7923E-11	-2.2402E-13	1.9415E-16	-6.8130E-20	8.9308E-24
5	1.1636E-06	-5.0434E-10	9.6131E-12	-1.7599E-14	1.7162E-17	-5.8680E-21
6	1.2711E-06	9.8638E-09	-3.6063E-11	1.0124E-13	-1.3184E-16	7.2290E-20
7	-1.2711E-06	-9.8638E-09	3.6063E-11	-1.0124E-13	1.3184E-16	-7.2290E-20
8	-1.1636E-06	5.0434E-10	-9.6131E-12	1.7599E-14	-1.7162E-17	5.8680E-21
12	3.2814E-08	-7.2202E-10	7.5840E-13	-9.3077E-17	-4.2291E-19	2.0621E-22
14	-7.2374E-07	-1.6695E-10	2.2119E-13	-1.0836E-16	2.7162E-20	-2.7258E-24

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: -660.40 θ: 2.40 MAG: -0.0800
EFL: 65.9971 FVD: 294.905 ENP: 47.4196
IMD: 9.97716 BRL: 284.928 EXP: 1143.16
OBD: -773.714 OVL: 1068.62
STOP: 21.56 after surface 6. DIA: 46.429

TABLE 6

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1	137.0489	5.00000	BK7	74.99
2	31.2291	25.38251		55.45
3a	-113.5269	10.00000	STYRENE	53.14
4a	-54.9945	0.27919		51.38
5a	35.0988	7.44470	ACRYLIC	41.08
6a	27.6177	32.99456		35.67
7a	-27.6177	7.44470	ACRYLIC	41.91
8a	-35.0988	0.20000		49.19
9	131.8282	18.00000	ACRYLIC	65.15
10a	-43.7525	1.00000		65.04
11a	-51.4270	7.00000	STYRENE	63.68
12a	-152.4864	0.27919		68.56
13	182.0921	20.00000	SK5	72.41
14	-54.1632	1.00000		72.95
15a	-51.4270	7.00000	STYRENE	70.79
16a	-152.4864	106.00550		72.42
17a	98.8869	15.00000	ACRYLIC	107.66
18	-535.3889	10.00007		107.59

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
3	3.4568E-06	6.9663E-10	2.6127E-12	-2.2808E-15	-9.7531E-19	8.0804E-22
4	5.3904E-06	-1.1902E-09	1.2013E-12	1.2557E-15	-6.8366E-18	3.1269E-21
5	1.0872E-06	4.9518E-09	1.3457E-11	-1.1151E-14	2.3531E-17	-2.2802E-20
6	-3.4949E-06	1.5294E-08	-1.8952E-11	1.2355E-13	-8.4255E-17	-3.7518E-20
7	3.4949E-06	-1.5294E-08	1.8952E-11	-1.2355E-13	8.4255E-17	3.7518E-20
8	-1.0872E-06	-4.9518E-09	-1.3457E-11	1.1151E-14	-2.3531E-17	2.2802E-20
10	-4.1719E-08	1.5484E-10	-8.0567E-14	-2.9683E-17	2.9631E-20	1.9686E-22
11	-9.0200E-08	2.5863E-10	3.5923E-13	1.8652E-16	-1.0960E-20	-9.8571E-23
12	7.9728E-07	4.3196E-10	2.6990E-14	1.1861E-16	1.3851E-19	-1.2450E-22
15	-9.0200E-08	2.5863E-10	3.5923E-13	1.8652E-16	-1.0960E-20	-9.8571E-23
16	7.9728E-07	4.3196E-10	2.6990E-14	1.1861E-16	1.3851E-19	-1.2450E-22
17	-2.6796E-07	-5.5252E-10	2.8672E-13	-7.5158E-17	1.4050E-20	-1.3844E-24

TABLE 6-continued

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −660.40	f/: 2.60	MAG: −0.0800
EFL: 66.0000	FVD: 274.030	ENP: 37.2913
IMD: 10.0001	BRL: 264.030	EXP: 832.590
OBD: −782.448	OVL: 1056.48	
STOP: 16.50 after surface 6. DIA: 37.551		

TABLE 7

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1	135.2710	4.00000	BK7	81.82
2	32.6261	17.79263		60.30
3a	928.2989	8.00000	STYRENE	60.02
4a	−188.2154	0.50000		58.30
5a	39.5052	8.00000	ACRYLIC	49.72
6a	29.1122	41.85327		41.46
7a	−29.1122	8.00000	ACRYLIC	44.58
8a	−39.5052	0.50000		52.98
9	77.5787	29.60778	ACRYLIC	71.42
10a	−45.4335	0.50000		72.42
11a	−57.8443	7.00000	STYRENE	69.57
12a	−218.1154	0.50000		72.44
13	146.0073	23.00000	SK5	75.52
14	−61.4748	1.00000		76.13
15a	−57.8443	7.00000	STYRENE	74.07
16a	−218.1154	107.76800		75.20
17a	113.1712	17.00000	ACRYLIC	105.00
18	−550.0000	10.00180		105.00

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
3	5.0114E-06	−7.5514E-10	2.4260E-12	−3.0219E-15	5.5886E-18	−3.8759E-21
4	5.0095E-06	−2.2665E-09	1.4239E-12	4.0511E-15	−6.9969E-18	1.3974E-21
5	7.0937E-07	2.8241E-09	2.5376E-12	−1.0416E-14	2.2718E-17	−1.3796E-20
6	−1.8225E-06	8.2637E-09	−2.6049E-11	5.5754E-14	−1.1258E-17	−2.3992E-20
7	1.8225E-06	−8.2637E-09	2.6049E-11	−5.5754E-14	1.1258E-17	2.3992E-20
8	−7.0937E-07	−2.8241E-09	−2.5376E-12	1.0416E-14	−2.2718E-17	1.3796E-20
10	9.0618E-07	3.6080E-10	3.6043E-13	−5.0548E-17	−1.1699E-19	9.1943E-23
11	4.0369E-07	3.0556E-10	−1.3767E-14	1.9427E-17	−7.0592E-20	1.5278E-23
12	9.8470E-07	3.0898E-10	4.5631E-14	−1.1394E-16	7.0842E-20	−2.2792E-23
15	4.0369E-07	3.0556E-10	−1.3767E-14	1.9427E-17	−7.0592E-20	1.5278E-23
16	9.8470E-07	3.0898E-10	4.5631E-14	−1.1394E-16	7.0842E-20	−2.2792E-23
17	−1.9051E-07	−5.7486E-10	3.1763E-13	−2.3064E-17	−2.4265E-20	5.2053E-24

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −571.50	f/: 2.40	MAG: −0.0889
EFL: 63.6601	FVD: 292.024	ENP: 39.9528
IMD: 10.0018	BRL: 282.022	EXP: 1252.22
OBD: −672.976	OVL: 964.999	
STOP: 28.85 after surface 6. DIA: 42.357		

TABLE 8

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	−430.6481	6.00000	ACRYLIC	107.85
2	48.2160	49.80489		80.00
3a	33.1764	11.00000	STYRENE	53.50
4a	71.0748	20.43078		50.56
5	Aperture stop	9.69367		36.95
6a	−27.0513	6.00000	STYRENE	36.45
7a	−97.7574	0.50000		43.38
8	−217.3178	4.00000	SF6	45.12
9	71.5467	15.00000	SK5	52.47
10	−85.2621	1.50000		58.77
11	113.6252	24.00000	SK5	85.23
12	−87.6248	0.50000		87.02
13	−1396.4110	12.00000	ACRYLIC	87.41

TABLE 8-continued

14a	−113.7844	106.02420		87.80
15a	144.0855	15.00000	ACRYLIC	108.71
16	−700.0000	10.00063		108.42

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
1	1.7265E-06	−5.0563E-10	7.7902E-14	1.8312E-17	−9.8919E-21	1.2219E-24
3	−6.4208E-07	−1.6867E-10	6.0966E-12	−3.8355E-15	−1.2448E-17	1.9858E-20
4	2.6200E-07	4.2710E-09	−2.4430E-12	−2.2089E-14	5.7230E-17	−3.7237E-20
6	−8.7022E-07	−4.6900E-09	6.8501E-12	−8.6392E-15	−1.1384E-16	2.0230E-19
7	−1.2079E-06	−1.3813E-09	3.5311E-12	−2.4985E-15	−1.2281E-17	1.9686E-20
14	1.0200E-06	2.3230E-10	−6.0636E-14	1.3854E-17	−4.5648E-21	2.7866E-24
15	−6.4501E-08	7.6368E-12	−4.1252E-14	1.1774E-17	2.6866E-21	−9.8906E-25

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −660.40 f/: 2.40 MAG: −0.0800
EFL: 66.1377 FVD: 291.454 ENP: 48.7648
IMD: 10.0006 BRL: 281.454 EXP: −7335.50
OBD: −778.552 OVL: 1070.01
STOP: 0.00 after surface 5. DIA: 36.951

TABLE 9

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	82.0969	5.00000	ACRYLIC	56.46
2	28.7214	11.21390		45.40
3	81.0110	8.00000	SF6	43.94
4	−887.3628	0.20000		41.52
5a	35.6781	7.50818	STYRENE	35.54
6a	23.2152	30.23279		27.37
7a	−23.2152	7.50818	STYRENE	27.06
8a	−35.6781	0.20000		34.74
9	−218.3648	24.00000	FK5	39.13
10	−25.2037	3.75409	SF6	46.27
11	−45.3202	0.20000		57.07
12	114.2101	18.00000	SK5	72.21
13	−70.4229	0.20000		72.72
14a	−139.1289	9.00000	ACRYLIC	71.25
15a	−61.2332	74.18505		71.52

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
1	1.1388E-06	−5.2355E-10	−1.6178E-12	3.7438E-15	−3.4246E-18	1.2570E-21
5	−1.1687E-06	1.7395E-08	−3.2445E-11	1.6996E-13	−3.2950E-16	4.3388E-19
6	−6.1381E-06	3.2753E-08	−6.9297E-11	−4.1770E-13	4.7770E-15	−8.9615E-18
7	6.1381E-06	−3.2753E-08	6.9297E-11	4.1770E-13	−4.7770E-15	8.9615E-18
8	1.1687E-06	−1.7395E-08	3.2445E-11	−1.6996E-13	3.2950E-16	−4.3388E-19
14	−2.9437E-07	−5.0363E-10	1.2027E-13	−1.1975E-16	2.5254E-19	−9.5080E-23
15	1.8908E-06	−7.2759E-11	−4.3346E-14	−6.5028E-17	2.5433E-19	−9.1037E-23

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −317.50 f/: 2.00 MAG: −0.0800
EFL: 42.9995 FVD: 199.202 ENP: 37.7574
IMD: 74.1850 BRL: 125.017 EXP: −125100.
OBD: −499.751 OVL: 698.953
STOP: 17.95 after surface 6. DIA: 24.093

TABLE 10

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	25.2237	2.50000	ACRYLIC	18.90
2	8.3453	4.06293		14.11

TABLE 10-continued

3	73.7767	1.00000	BK7	13.93
4	18.7852	4.00000	SF6	13.37
5	−47.7215	0.20000		12.51
6a	13.8802	2.00000	ACRYLIC	10.40
7a	8.6569	7.11753		8.20
8a	−8.6569	2.00000	ACRYLIC	6.78
9a	−13.8802	0.20000		7.81
10	−28.7358	1.00000	SF6	8.10
11	10.9118	8.33000	BK7	9.36
12	−11.9366	0.20000		14.66
13a	25.8279	9.37000	ACRYLIC	18.57
14a	−12.4324	1.40000		20.59
15	∞	31.20000	SK5	18.92
16	∞	0.47810		13.70

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
1	1.3074E-05	5.5412E-07	−3.3729E-08	6.3765E-10	−5.4661E-12	1.8213E-14
6	1.8844E-04	2.5379E-05	−8.6379E-07	2.4831E-08	−2.6633E-10	6.8303E-12
7	1.9187E-04	3.2358E-05	1.1808E-07	−1.3481E-07	9.4399E-09	−1.3832E-10
8	−1.9187E-04	−3.2358E-05	−1.1808E-07	1.3481E-07	−9.4399E-09	1.3832E-10
9	−1.8844E-04	−2.5379E-05	8.6379E-07	−2.4831E-08	2.6633E-10	−6.8303E-12
13	−4.3807E-05	−4.1408E-07	1.6296E-09	−2.2920E-11	3.8303E-13	−3.5993E-15
14	5.9546E-05	7.1410E-08	−1.7909E-09	−1.9090E-11	6.0683E-13	−3.3412E-15

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −557.00 f/: 2.00 MAG: −0.0122
EFL: 11.4542 FVD: 75.0586 ENP: 13.3134
IMD: 0.478098 BRL: 74.5805 EXP: −14279.3
OBD: −925.562 OVL: 1000.62
STOP: 5.76 after surface 7. DIA: 6.7154

TABLE 11

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	281.6491	6.00000	ACRYLIC	51.59
2	34.3557	7.49190		42.42
3	77.3775	6.00000	SF6	40.94
4	∞	3.00000	BK7	39.23
5	59.3087	0.20000		35.58
6a	26.2016	9.00000	ACRYLIC	33.32
7a	27.7133	23.27822		26.98
8	∞	28.10182		14.82
9a	−27.7133	9.00000	ACRYLIC	33.30
10a	−26.2016	0.20000		40.12
11	−64.1761	14.00000	SK5	44.51
12	−30.1775	3.00000	SF6	48.81
13	−54.2642	0.20000		56.09
14	271.8037	17.00000	BK7	63.66
15	−54.6869	0.20000		65.35
16a	−110.0000	8.00000	ACRYLIC	64.68
17a	−80.0000	4.50000		66.93
18	∞	4.50000	BK7	64.69
19	∞	1.00000		64.18
20	∞	55.00000	SSK5	64.00
21	∞	72.33000	SK5	58.23
22	∞	3.00000	BK7	50.29
23	∞	0.50000		49.95
24	∞	3.18000	BK7	49.86
25	∞	−0.09453		49.51

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
1	2.7021E-06	−4.2909E-10	−7.4454E-13	1.1622E-15	−3.5089E-19	−1.7018E-22
6	1.5256E-06	−1.1915E-09	3.2360E-11	−3.5262E-13	1.1495E-15	−1.2915E-18
7	6.4649E-06	4.6582E-08	−4.6274E-10	1.9572E-12	−3.0717E-15	1.0689E-19
9	−6.4649E-06	−4.6582E-08	4.6274E-10	−1.9572E-12	3.0717E-15	−1.0689E-19
10	−1.5256E-06	1.1915E-09	−3.2360E-11	3.5262E-13	−1.1495E-15	1.2915E-18
16	−8.2477E-08	−4.9723E-10	−6.0851E-13	−3.0556E-16	−1.5484E-19	1.4939E-22
17	6.0090E-07	−5.7431E-10	−3.7456E-13	−2.4739E-16	−2.6086E-20	7.7311E-23

TABLE 11-continued

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −359.20	f/: 4.00	MAG: −0.0689
EFL: 47.9726	FVD: 278.587	ENP: 39.1924
IMD: −.945269E-01	BRL: 278.682	EXP: 35216.9
OBD: −657.006	OVL: 935.593	
STOP: 0.00 after surface 8. DIA: 14.775		

TABLE 12

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	−490.1644	5.00000	ACRYLIC	60.02
2	30.5001	16.98608		47.16
3	47.9748	8.00000	SF6	44.43
4	147.4488	0.20000		42.06
5a	23.7369	7.50818	ACRYLIC	35.86
6a	20.6264	34.28608		28.97
7	523.9152	8.00000	SK5	19.05
8	−15.4998	1.00000	F2	21.21
9	1881.4011	8.10173		24.35
10a	−20.6264	7.50818	ACRYLIC	27.29
11a	−23.7369	0.20000		34.29
12	−56.2662	15.00000	FK5	38.40
13	−25.3606	3.00000	NBFD10	43.58
14	−39.6161	0.20000		50.92
15a	108.2844	18.00000	ACRYLIC	62.68
16a	−43.0795	1.00000		63.55
17	∞	120.00000	SK5	61.78
18	∞	0.96650		50.95

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
1	3.6956E-06	−2.0636E-09	1.1625E-13	2.0365E-15	−2.5214E-18	1.0960E-21
5	5.4411E-08	5.7772E-09	1.4208E-10	−1.0278E-12	3.6326E-15	−3.9867E-18
6	−1.0290E-06	8.6170E-08	−1.0754E-09	6.1660E-12	−1.1913E-14	6.1467E-18
10	1.0290E-06	−8.6170E-08	1.0754E-09	−6.1660E-12	1.1913E-14	−6.1467E-18
11	−5.4411E-08	5.7772E-09	−1.4208E-10	1.0278E-12	−3.6326E-15	3.9867E-18
15	2.0070E-08	−3.2885E-10	−2.2938E-13	2.6744E-16	−1.3675E-19	1.8952E-23
16	2.0828E-06	5.4647E-10	−1.6157E-15	−2.1816E-16	3.2489E-19	−1.2073E-22

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −317.50	f/: 4.00	MAG: −0.0800
EFL: 42.9997	FVD: 254.957	ENP: 40.3017
IMD: 0.966499	BRL: 253.990	EXP: 29407.9
OBD: −497.132	OVL: 752.089	
STOP: −22.18 after surface 8. DIA: 13.044		

TABLE 13

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	570.3171	5.00000	ACRYLIC	54.10
2	31.9481	13.60849		43.71
3	64.3459	6.00000	SF6	39.79
4	162.9577	0.20000		37.59
5a	23.3904	7.50818	STYRENE	32.55
6a	20.8846	43.31920		25.76
7a	−20.8846	7.50818	STYRENE	28.40
8a	−23.3904	0.20000		35.51
9	−63.5258	15.00000	SK5	40.56
10	−24.2464	3.00000	SF6	44.03
11	−47.5492	0.20000		53.60
12a	118.4054	18.00000	ACRYLIC	64.24
13a	−42.3194	1.00000		64.99
14	∞	120.00000	SK5	62.82
15	∞	0.97044		50.97

TABLE 13-continued

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
1	3.5234E-06	−2.1582E-09	1.0051E-13	2.2823E-15	−2.6612E-18	1.1080E-21
5	4.1438E-07	−2.6927E-09	1.4331E-10	−1.0171E-12	3.6740E-15	−4.2041E-18
6	9.6270E-07	9.1133E-08	−1.0091E-09	6.2227E-12	−1.2776E-14	7.3793E-18
7	−9.6270E-07	−9.1133E-08	1.0091E-09	−6.2227E-12	1.2776E-14	−7.3793E-18
8	−4.1438E-07	2.6927E-09	−1.4331E-10	1.0171E-12	−3.6740E-15	4.2041E-18
12	−7.3105E-08	−4.0309E-10	−2.9597E-13	1.8337E-16	−1.8251E-19	4.9664E-23
13	1.8625E-06	5.9249E-10	−6.5396E-14	−2.9205E-16	2.6928E-19	−1.5540E-22

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −317.50	f/: 4.00	MAG: −0.0800
EFL: 42.9986	FVD: 241.514	ENP: 36.9733
IMD: 0.970439	BRL: 240.544	EXP: 83338.6
OBD: −500.487	OVL: 742.002	
STOP: 20.66 after surface 6. DIA: 12.825		

TABLE 14

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	−256.3043	5.12507	ACRYLIC	38.68
2	25.8020	16.91454		32.83
3	57.0870	5.97924	SF11	32.44
4	314.5539	0.17084		31.33
5a	27.3894	7.14803	ACRYLIC	29.45
6a	31.8678	22.44155		25.28
7	Aperture stop	11.95012		16.02
8	−374.6280	7.00000	FK52	21.41
9	−16.9616	1.00000	KZFS4	22.61
10	−225.3529	3.20881		25.18
11a	−31.8678	7.14803	ACRYLIC	25.59
12a	−27.3894	0.17084		30.27
13	−35.1092	2.56253	KZFS4	31.20
14	54.9984	15.00000	FK52	38.26
15	−46.5677	0.17084		43.81
16	78.5015	15.00000	SK5	52.30
17	−51.5058	0.20000		52.92
18a	−100.0000	7.00000	ACRYLIC	51.34
19a	−80.0000	0.85418		51.17
20	∞	46.97978	SSK5	50.15
21	∞	71.75093	SK5	43.32
22	∞	0.42709		32.42
23	∞	2.76754	K5	32.32
24	∞	−0.00139		31.88

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
1	6.2110E-06	−3.8544E-09	−4.3180E-12	2.5385E-14	−5.1475E-17	4.9727E-20
5	3.7087E-06	1.2867E-08	1.0134E-10	−1.0412E-12	6.7191E-15	−1.3018E-17
6	6.0690E-06	7.9141E-08	−9.6884E-10	8.0294E-12	−2.2874E-14	1.3079E-17
11	−6.0690E-06	−7.9141E-08	9.6884E-10	−8.0294E-12	2.2874E-14	−1.3079E-17
12	−3.7087E-06	−1.2867E-08	−1.0134E-10	1.0412E-12	−6.7191E-15	1.3018E-17
18	−3.5771E-08	−7.9681E-10	−2.2928E-12	1.3144E-15	−1.0852E-18	1.9977E-21
19	2.5145E-06	−7.4160E-10	6.8492E-13	−2.5957E-15	1.0395E-18	1.9495E-21

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −279.40	f/: 3.3 3	MAG: −0.0570
EFL: 40.9984	FVD: 250.969	ENP: 33.7610
IMD: −.1 39194E-02	BRL: 250.970	EXP: −17586.0
OBD: −685.605	OVL: 936.574	
STOP: 0.00 after surface 7. DIA: 16.008		

TABLE 15

SN.	RADIUS	THICKNESS	GLASS	CLR. AP.
1a	260.9710	5.12507	ACRYLIC	42.31
2	25.6475	19.11514		35.39
3	47.2190	5.97924	SF11	33.32

TABLE 15-continued

4	67.5626	0.17084		31.38
5a	25.4264	7.14803	STYRENE	30.15
6a	30.1914	48.40961		25.95
7a	−30.1914	7.14803	STYRENE	26.42
8a	−25.4264	0.17084		30.85
9	−31.4535	2.56253	SF5	31.48
10	50.0514	15.00000	SK5	39.00
11	−72.6714	0.17084		45.09
12	69.0035	15.00000	SK5	53.47
13	−49.8407	0.20000		53.76
14a	−100.0000	7.00000	ACRYLIC	51.80
15a	−80.0000	0.85418		51.84
16	∞	46.97978	SSK5	50.72
17	∞	71.75093	SK5	43.67
18	∞	0.42709		32.43
19	∞	2.76754	K5	32.32
20	∞	0.00529		31.87

EVEN POLYNOMIAL ASPHERES

SN.	AD	AE	AF	AG	AH	AI
1	5.3384E-06	−7.9525E-10	−7.5835E-12	1.6616E-14	−1.9565E-17	1.6420E-20
5	2.6012E-07	8.8368E-09	1.0831E-10	−1.0908E-12	6.9609E-15	−1.3602E-17
6	3.9652E-06	9.1183E-08	−1.0645E-09	8.3839E-12	−2.2080E-14	8.4275E-18
7	−3.9652E-06	−9.1183E-08	1.0645E-09	−8.3839E-12	2.2080E-14	−8.4275E-18
8	−2.6012E-07	−8.8368E-09	−1.0831E-10	1.0908E-12	−6.9609E-15	1.3602E-17
14	−7.0826E-07	−1.2109E-09	−2.6870E-12	9.5720E-16	−1.3980E-18	2.1217E-21
15	2.2587E-06	−6.8697E-10	7.6586E-13	−2.9386E-15	2.4725E-19	2.2444E-21

SYSTEM FIRST ORDER PROPERTIES

OBJ. HT: −279.40 f/: 3.33 MAG: −0.0570
EFL: 41.0016 FVD: 255.985 ENP: 38.9501
IMD: 0.528695E-02 BRL: 255.980 EXP: −7950.90
OBD: −680.588 OVL: 936.573
STOP: 25.77 after surface 6. DIA: 16.215

TABLE 16

MATERIALS TABLE

Name	N_e	V_e
Acrylic	1.4938	56.9
Styrene	1.5949	30.7
SK5	1.5914	61.0
SF6	1.8126	25.2
SF14	1.7686	26.3
BK7	1.5187	63.9
F2	1.6241	36.1
SF11	1.7919	25.5
FK52	1.4874	81.4

TABLE 16-continued

MATERIALS TABLE

Name	N_e	V_e
KZFS4	1.6167	44.1
SSK5	1.6615	50.6
K5	1.5246	59.2
SF5	1.6776	31.9
NBFD10	1.8393	37.1
FK5	1.4891	70.2

TABLE 17

Ex. No.	Field	F/No	f	f_1	f_2	f_3	ASOD	ENPD	ASOD/f
1	38.8°	2.4	65.61	−74.33	−804.19	79.61	209.76	−13189.8	3.2
2	38.8°	2.4	66.00	−101.66	403.81	88.48	192.91	933.9	2.9
3	38.8°	2.4	65.65	−81.46	−523.66	78.88	208.40	−11068.7	3.2
4	38.6°	2.6	66.19	−60.07	529.72	81.76	202.18	−6205.6	3.1
5	38.8°	2.4	66.00	−75.56	184.44	113.70	199.23	1143.2	3.0
6	38.9°	2.6	66.00	−79.25	665.38	111.01	209.42	832.6	3.2
7	38.8°	2.4	63.37	−84.01	−468.50	110.74	223.92	1282.9	3.5
8	38.6°	2.4	66.14	−87.45	563.82	79.21	204.21	−7335.5	3.1
9	30.6°	2.0	43.00	−92.37	1671.63	47.84	149.33	−125100.0	3.5
10	30.7°	2.0	11.45	−26.57	96.26	13.76	55.54	−14279.3	4.9
11	27.3°	4.0	47.97	−79.88	155.64	73.82	223.71	35216.9	4.7
12	30.6°	4.0	43.00	−58.00	90.84	57.29	197.12	29407.9	4.6
13	30.6°	4.0	43.00	−68.79	120.70	58.89	186.53	83338.6	4.3
14	21.2°	3.3	41.00	−47.19	71.64	57.96	193.19	−17586.0	4.7
15	21.2°	3.3	41.00	−58.00	84.11	70.56	192.67	−7950.9	4.7